MS 115a, Problem Set #6

1. List and describe three (not more!) strengthening mechanisms used to enhance the mechanical properties of metals.

2. Suppose you have a single crystal of a cubic close-packed metal which is known to have a critical resolved shear stress of 61.8 MPa.

   (a) Find the largest normal stress that could be applied to a bar of this material in the [1 1 2] direction before dislocations begin to move in the [$\bar{1}$ 0 1] direction in the (1 1 1) plane.

   (b) Now let this be a body centered cubic metal with slip system [1 1 1]($\bar{1}$ 0 1). Find the largest normal stress that could be applied in the [1 1 2] direction.

3. (a) Calculate the critical resolved shear stress in a crystal if a stress of 265 MPa in the [1 0 0] direction is required to move a dislocation in the [1 1 $\bar{1}$] direction on the (1 0 1) plane.

   (b) Is this a BCC or CCP metal? Why?

4. The yield stress of an aluminum alloy is 132 MPa. A specimen has a diameter of 0.01 m and a length of 0.10 m. It is loaded in tension to 1,000 N and deflects 1.81×10^{-5} m.

   (a) Compute whether the stress is above or below the yield stress.

   (b) Assuming the stress is less than the yield stress, calculate Young's modulus.

5. Young's moduli for Al, Cu and W are 70,344, 120,550 and 393,072 MPa, respectively. Assuming the materials do not yield, compute the deflections in specimens of each material when subjected to a load of 5,000 N. The specimens are 1.00 m long with a cross section of 1.0 cm × 1.0 cm.

6. Problem 10.19 from the textbook "Understanding Solids" by Tilley. Note, gauge length, l_0, is the length over which the strain is felt. The term is used because in a tensile measurement the material is shaped to include grips (a 'dog-bone' shape) and the grip length is not part of l_0. Note also in Figure 10.11(b) the value 0.02% should be 0.2%.

7. The strength of aluminum oxide (alumina) can be as high as 4,200 MPa and the fracture toughness can be as low as 2.5 MPa √m. A sample of alumina contains flaws that are 50 μm or less in size. Estimate the stress at which fracture will occur in this specimen.

8. Griffith's equation implies that the theoretical fracture strength of a material depends on its surface energy and Young's modulus. The fracture toughness of a material, K_C, is an inherent material property that is proportional to the theoretical fracture strength (to within a geometric constant that depends on the orientation of the stress relative to the fracture and other geometric considerations). The fracture toughness of metals is generally higher than that of ceramics. It was noted in lecture that in the case of metals, the surface energy term in the Griffith equation should be modified to include the effect of yielding or plastic deformation occurring at the crack tip. If the conventional surface energies of ceramics and

metals are comparable (with respect to air) and the fracture toughness of a typical metal is about 100 times that of a typical ceramic, how much is the effective surface energy modified as a result of the yield?

9. Using what has been covered in lecture about the theoretical fracture strength of brittle materials, derive a relationship between Young's modulus and surface energy.

10. MgO has a surface energy of 1050 erg/cm^2 (with respect to air). After a thermal etch, it is observed that the pits formed at grain boundaries have an interior angle of 140°. What is the grain boundary surface energy?

11. An asymmetric tilt boundary is shown in the figure below. Show that the distance between edge dislocations is given by the magnitude of the burgers vectors and the relevant angles according to $D_\perp = \dfrac{b_\perp}{\theta \cos \phi}$ and $D_{|-} = \dfrac{b_{|-}}{\theta \sin \phi}$
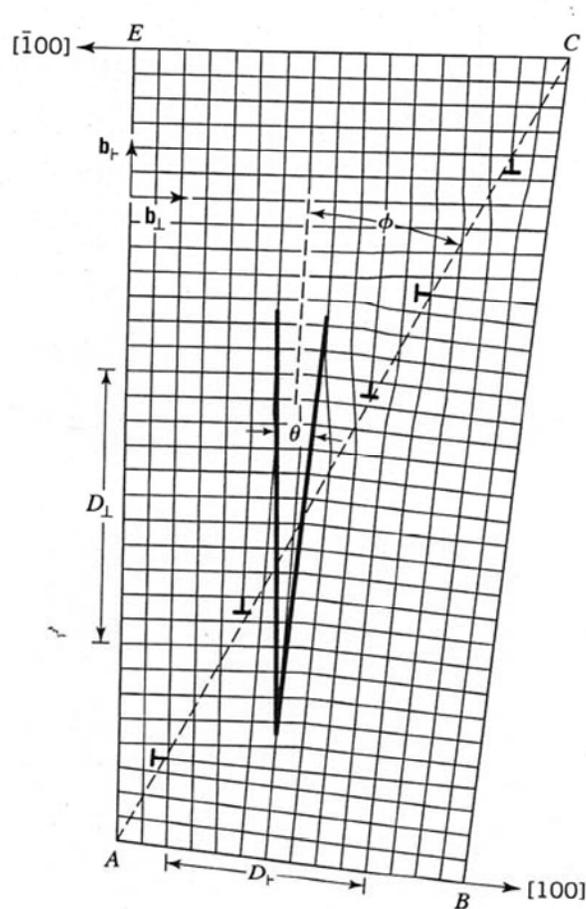
12. Optional - please indicate whether you intend to enroll in MS/ME 162 (Greer), which effectively replaces MS 115b this winter, and if you intend to enroll in MS 90 this spring.